Notice No.2

Rules for the Manufacture, Testing and Certification of Materials, July 2022

The status of this Rule set is amended as shown and is now to be read in conjunction with this and prior Notices. Any corrigenda included in the Notice are effective immediately.

Please note that corrigenda amends to paragraphs, Tables and Figures are not shown in their entirety.

Issue date: June 2023

Amendments to	**Adoption Date**	**Applicable Date**
Chapter 1, Sections 4 & 6	1 July 2023	N/A
Chapter 2, Section 9	1 July 2023	N/A
Chapter 3, Sections 1, 2, 3, 4, 6 & 7	1 July 2023	N/A
Chapter 4, Sections 8 & 10 (New)	1 July 2023	N/A
Chapter 5, Section 9	1 July 2023	N/A
Chapter 6, Section 5	1 July 2023	N/A
Chapter 8, Section 1	1 July 2023	N/A
Chapter 10, Section 6	1 July 2023	N/A
Chapter 13, Section 8	1 July 2023	N/A

Chapter 1
General Requirements

■ *Section 4*
General requirements for manufacture

4.1 General

4.1.1 The following definitions are applicable to these Rules:

Wide Flat: flat product of a width over 150 mm, up to and including 1250 mm and thickness generally over 4 mm. Edges are square ~~cut~~, i.e. hot rolled on the four sides (or in box passes). Always ~~S~~supplied in lengths, not coils.

■ *Section 6*
References

6.1 General

(*Part only shown*)

Table 1.6.1 List of National ~~standards~~ Standards

Rule reference	Standard
Chapter 2 - Testing Procedures for Metallic Materials	ASTM A262 ASTM G48
Chapter 3 - Rolled Steel Plates, Strip, Sections and Bars	EN 10163-3
Chapter 4 – Steel Castings	ISO 6892-1 ISO 148-1
Chapter 10 – Equipment for Mooring and Anchoring	ISO 7800 ISO 7802 EN 10264-2 EN 10264-3 EN 10244-1 EN 10244-2

Chapter 2
Testing Procedures for Metallic Materials

■ *Section 9*
Corrosion tests

9.1 Intergranular corrosion test

Existing paragraphs 9.1.1 to 9.1.5 have been deleted and replaced with the following:

9.1.1 When intergranular corrosion testing is required, the test shall be carried out in accordance with ASTM A262 *Practice E, Copper - Copper Sulphate - Sulphuric Acid Test*. Tests carried out in compliance with other recognised National/International Standards may be accepted subject to agreement with LR. The test is to reveal no sensitivity to intergranular corrosion.

9.1.2 When required, a flattening test shall be conducted in accordance with *Ch 2, 4.2 Flattening tests*. After flattening or bending, the test specimens are to be free from cracks on the outer, convex surface.

9.2 Pitting corrosion test

Existing paragraphs 9.2.1 to 9.2.11 have been deleted and replaced with the following:

9.2.1 For test requirements where pitting corrosion resistance is specified, the appropriate corrosion tests shall be carried out in accordance with ASTM G48 *Method A*.

9.2.2 Cut edges shall be prepared according to ASTM G48. The whole specimen shall be pickled before being weighed and tested. Pickling shall be performed for five minutes at 60°C in a solution of 20 per cent nitric acid added to 5 per cent hydrofluoric acid. The acceptance criteria are:

- No pitting at x20 magnification;
- The specimen mass loss shall be less than 4,0 g/m^2.

9.2.3 The test specimens shall be exposed to the solution at a constant temperature of 22 ± 2°C for type 22Cr duplex (S31803) and 50 ± 2°C for type 25Cr duplex (S32750) for 24 hours. No pitting on specimen surfaces is allowed when viewed at x20 magnification. The specimen mass loss shall be less than 4,0 g/m^2.

Chapter 3
Rolled Steel Plates, Strip, Sections and Bars

■ *Section 1*
General requirements

1.5 Surface quality of materials

1.5.3 For hot rolled plates, wide flats and sections, the surface quality inspection method shall be in accordance with recognised National or International Standards as agreed between the purchaser and the manufacturer, and accepted by LR. The surface inspection acceptance criteria are to comply with the following:

(a) Imperfections
Imperfections of a harmless nature, for example pitting, rolled-in scale, indentations, roll marks, scratches and grooves, regarded as being inherent in the manufacturing process, are permissible, provided the maximum permissible limits of Class A of EN 10163-2 for plates and wide flats and the permissible limits of Class C of EN 10163-3 for sections, or limits specified in a recognised equivalent standard accepted by LR, are not exceeded and the remaining plate or wide flat thickness remains within the average allowable minus thickness tolerance specified in *Ch 3, 1.7 Dimensional tolerances*. The surface area exhibiting the imperfections is not to exceed 15 per cent of the total subject area.

(b) Defects
Affected areas with imperfections with a depth exceeding the limits of Class A of EN 10163-2 for plates and wide flats and the limits of Class C of EN 10163-3 for sections, or the maximum permissible limits specified in a recognised equivalent standard accepted by LR, shall be cause for rejection or repair~~ed~~. Cracks, injurious surface flaws, shells (overlapping material with non-metallic inclusion), sand patches, laminations and sharp edged seams (elongated defects) visually evident on the surface and/or edge of the plate are considered defects which would impair the end use of the product and ~~which~~ shall be cause for ~~require~~ rejection or repair.

■ *Section 2*
Normal strength steels for ship and other structural applications

2.3 Condition of supply

(Part only shown)
Table 3.2.2 Condition of supply

Grade	Thickness *t* mm	Conditions of supply
A and B	~~≤50~~ $t \le 50$	Any (*see* Note 1)
	~~>50 ≤100~~ $50 < t \le 150$	N NR TM (*see* Note 2)
D	~~≤35~~ $t \le 35$	Any (*see* Note 1)
	~~>35 ≤100~~ $35 < t \le 150$	N NR TM (*see* Note 3)
E	~~≤100~~ $t \le 150$	N TM (*see* Note 4)
N = normalised NR = normalising rolled TM = thermomechanically controlled-rolled		

2.4 Mechanical tests

(Part only shown)

Table 3.2.3 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65~~$\sqrt{S_o}$~~ $\sqrt{S_o}$% minimum	Charpy V-notch impact test (*see* Notes 3~~,~~ and 4~~, 5, 6~~)		
				Thickness t mm	Average energy J minimum	
					Longitudinal	Transverse
A, B, D, E	235	~~400 - 520~~ 400–520 (~~see~~ *See* Note 1)	22 (~~see~~ *see* Note 2)	~~≤50~~ $t \le 50$ ~~>50 ≤70~~ $50 < t \le 70$ ~~>70 ≤100~~ $70 < t \le 150$	27 34 41	20 24 27
~~required~~20°C, where required (*see* Note 5) Impact tests are to be made on the various grades at the following temperatures: required (*see* Note 6)					A grade B grade D grade E grade	~~not~~ 0°C, where -20°C -40°C
Note *3. See Ch 3, 2.4 Mechanical tests 2.4.5* ~~and~~, *Ch 3, 2.4 Mechanical tests 2.4.6*, *Ch 3, 2.4 Mechanical tests 2.4.7* and *Ch 3, 2.4 Mechanical tests 2.4.8*. ~~**Note** *4. See Ch 3, 2.4 Mechanical tests 2.4.7*.~~ **Note** *~~5~~4. See Ch 3, 1.9 Test material and mechanical tests 1.9.11*. **Note** *5. See Ch 3, 2.4 Mechanical tests 2.4.5*. **Note** *6. See Ch 3, 2.4 Mechanical tests 2.4.6*.						

Existing paras 2.4.5 to 2.4.11 have been deleted and replaced with the following:

2.4.5 For Grade A steels:

(a) Charpy V-notch impact tests are not required when the thickness does not exceed 50 mm, or up to 100 mm thick if the material is supplied in either the normalised or thermomechanically controlled-rolled condition and has been fine grain treated. However, the manufacturer should confirm, by way of regular in-house checks, that the material will meet a requirement of 27 J at +20°C. The results of these checks shall be reported to the Surveyor. The frequency of these checks should as a minimum be every 250 tonnes.

(b) When supplied in a thickness greater than 50 mm up to 100 mm and either in the normalising rolled condition or when special approval has been given to supply in the as-rolled condition, a set of three impact test specimens is to be tested from each batch of 50 tonnes or fraction thereof.

(c) For thicknesses above 100 mm to a maximum thickness of 150 mm, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.6 For Grade B steels:

(a) Impact tests are not required for grade steels of 25 mm or less in thickness. However, the manufacturer is to confirm, by way of regular in-house tests, and on occasional material selected by the Surveyor, that the material meets the requirement of 27 J at 0°C. The results of the tests are to be reported to the Surveyor. The frequency of the in-house checks are to be, as a minimum, one set of three impact test specimens for every 250 tonnes.

(b) For thicknesses above 25 mm, supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

(c) For thicknesses above 25 mm, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.7 For Grade D steels:

(a) When supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

(b) When supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

Existing paragraphs 2.4.12 to 2.4.14 have been renumbered 2.4.8 to 2.4.10.

■ *Section 3*

Higher strength steels for ship and other structural applications

3.1 Scope

Table 3.3.1 Thickness limits

Steel designation				Thickness (~~t~~*t*) limit mm	
				Plate and wide flat	Sections and Bars
AH27S	DH27S	EH27S	FH27S	Maximum ~~100~~150	Maximum 50
AH32	DH32	EH32	FH32		
AH36	DH36	EH36	FH36		
AH40	DH40	EH40	FH40		
EH47				50 < ~~t~~*t* ≤ 100	Not applicable
Brittle Crack Arrest Steel		EH36-BCA1, EH40-BCA1, EH47-BCA1		50 < ~~t~~*t* ≤ 100	Not applicable
		EH40-BCA2, EH47-BCA2		80 < ~~t~~*t* ≤ 100	

3.3 Chemical composition

(Part only shown)

3.3.1 The chemical compositions of ladle samples for all grades of steel are to comply with the requirements of the approved manufacturing specification and the limits given in~~;~~:

- *Table 3.3.3 Carbon equivalent requirements for higher strength steels up to ~~100~~150 mm in thickness when supplied in the TM condition*, or

(Part only shown)

3.3.2 The carbon equivalent is to be calculated from the ladle analysis using the formula given below and is not to exceed the maximum value agreed between the fabricator and the steelmaker when the steel is ordered.

For TM steels, the agreed carbon equivalent is not to exceed the values given in *Table 3.3.3 Carbon equivalent requirements for higher strength steels up to ~~100~~150 mm in thickness when supplied in the TM condition*. For EH47 brittle crack arrest grade steels, the maximum carbon equivariant value is given in *Table 3.3.4 Chemical composition for brittle crack arrest steels*.

(Part only shown)

3.3.3 The maximum allowable P_{cm} is to be agreed with LR and is to be included in the manufacturing specification and reported on the certificate. For EH47 non brittle crack arrest steels, the maximum P_{cm} is given in *Table 3.3.3 Carbon equivalent requirements for higher strength steels up to ~~100~~150 mm in thickness when supplied in the TM condition*; for EH47 brittle crack arrest grade steels, the maximum P_{cm} value is given in *Table 3.3.4 Chemical composition for brittle crack arrest steels*.

Table 3.3.3 Carbon equivalent requirements for higher strength steels up to ~~100~~150 mm in thickness when supplied in the TM condition

Grades	Carbon Equivalent, max (%)		
	~~t≤50~~ *t* ≤ 50 mm ~~(Note 1)~~	50 < ~~t~~*t* ≤ 100 mm ~~(Note 1)~~	100 < *t* ≤ 150 mm
AH-27S DH-27S EH-27S FH-27S	~~0,36~~0,34	~~0,38~~0,36	0,38
AH-32 DH-32 EH-32 FH-32	0,36	0,38	0,40
AH-36 DH-36 EH-36 FH-36	0,38	0,40	0,42
AH-40 DH-40 EH-40 FH-40	0,40	0,42	0,45
EH47 (*see* Note ~~2~~)	Not applicable (*see Table 3.3.1 Thickness limits*)	0,49	-
~~**Note** 1. t = thickness in mm~~ **Note** ~~2~~. For EH47, the maximum ~~Pcm~~ P_{cm} is ~~0, 22%~~ 0,24%			

3.4 Condition of supply

(Part only shown)

Table 3.3.5 Conditions of supply for plates and wide flats

Grade	Grain refining practice (*see* Note 1)	Thickness range *t* mm	Conditions of supply (*see* Note 2)
AH 27S AH 32 AH 36	Al or Al + Ti	~~≤20~~ *t* ≤ 20 ~~>20 ≤ 100~~ 20 < *t* ≤ 150	AR N NR TM – N NR TM (*see* Note 3)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	~~≤12,5~~ *t* ≤ 12,5 ~~>12,5≤100~~ 12,5 < *t* ≤ 150	AR N NR TM – N NR TM

AH 40	Any practice	~~≤12,5~~ *t* ≤ 12,5 ~~>12,5 ≤ 50~~ 12,5 < *t* ≤ 50 ~~>50 ≤ 100~~ 50 < *t* ≤ 150	AR N NR TM – N NR TM – N – TM QT
DH 27S DH 32 DH 36	Al or Al + Ti	~~≤20~~ *t* ≤ 20 ~~>20 ≤ 100~~ 20 < *t* ≤ 150	AR N NR TM – N NR TM (*see* Note 4)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	~~≤12,5~~ *t* ≤ 12,5 ~~>12,5 ≤ 100~~ 12,5 < *t* ≤ 150	AR N NR TM – N NR TM
DH 40	Any practice	~~≤50~~ *t* ≤ 50 ~~>50 ≤ 100~~ 50 < *t* ≤ 150	– N NR TM – N – TM QT
EH 27S EH 32 EH 36	Any practice	~~≤100~~ *t* ≤ 150	– N – TM
EH 40	Any practice	~~≤100~~ *t* ≤ 150	– N – TM QT
FH 27S FH 32 FH 36 FH 40	Any practice	~~≤100~~ *t* ≤ 150	– N – TM QT
EH 47	Any practice	~~≤50~~ *t* ≤ 50	Not applicable
		~~> 50 ≤ 100~~ 50 < *t* ≤ 100	– – - TM QT
EH36-BCA1	Any practice	~~≤ 50~~ *t* ≤ 50	Not applicable
EH40-BCA1		~~>50 ≤ 100~~ 50 < *t* ≤ 100	- - - TM - (*see* Note 5)
EH40-BCA2			
EH47-BCA1			
EH47-BCA2			

(Part only shown)

Table 3.3.6 Conditions of supply for sections and bars

Grade	Grain refining practice (*see* Note 1)	Thickness range *t* mm
AH 27S AH 32 AH 36	Al or Al + Ti	~~≤20~~ *t* ≤20 ~~>20≤50~~ 20 < *t* ≤ 50
	Nb or V or Al + Nb or ~~A1+~~ Al + V or Al + (Ti) + (Nb or V)	~~≤12,5~~ *t* ≤ 12,5 ~~>12,5≤50~~ 12,5 < *t* ≤ 50
AH 40	Any practice	~~≤12,5~~ *t* ≤ 12,5 ~~>12,5≤50~~ 12,5 < *t* ≤ 50
DH 27S DH 32 DH 36	Al or Al + Ti	~~≤20~~ *t* ≤ 20 ~~>20≤50~~ 20 < *t* ≤ 50
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	~~≤12,5~~ *t* ≤ 12,5 ~~>12,5≤50~~ 12,5 < *t* ≤ 50
DH 40	Any practice	~~≤50~~ *t* ≤ 50
EH 27S EH 32 EH 36	Any practice	~~≤50~~ *t* ≤ 50
EH 40	Any practice	~~≤50~~ *t* ≤ 50
FH 27S FH 32 FH 36 FH 40	Any practice	~~≤50~~ *t* ≤ 50

3.5 Mechanical tests and brittle crack arrest property tests

(Part only shown)

Table 3.3.7 Mechanical properties for acceptance of higher strength steel (*see* Note 1)

Grades (*see* Notes 3 and 5)	Yield Stress N/mm^2 min.	Tensile Strength N/mm^2	Elongation on 5,65 ~~$\sqrt{S_o}$ %~~ $\sqrt{S_o}$% min. (*see* Note 2)	Charpy V-notch impact tests (*see* Notes ~~3, 4, 5 and 6~~ 4 and 7)					
				Average energy J minimum					
				~~t~~*t* ≤ 50 mm		50 < ~~t~~*t* ≤ 70 mm		70 < ~~t~~*t* ≤ ~~100~~150 mm	
				Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
EH47	460	570 - 720	17	(*see* Notes 4 and 6)					
~~Impact tests are to be made on the various grades at the following temperatures:~~ ~~AH grades 0°C~~ ~~DH grades -20°C~~ ~~EH grades -40°C~~ ~~FH grades -60°C~~									
Note *6*. The Charpy V-notch impact energy for EH47 in the longitudinal direction are as ~~the following~~ follows: 50 < ~~t~~*t* ≤ 70 mm 53J 70 < ~~t~~*t* ≤ 85 mm 64J 85 < ~~t~~*t* ≤ 100 mm 75J For EH47 steel grades, the thickness limit for Charpy V-notch impact tests shall be up to a maximum of 100 mm. **Note** *7*. Impact tests are to be made on the various grades at the following temperatures: AH grades 0°C DH grades -20°C EH grades -40°C FH grades -60°C									

■ *Section 4*
Steels for boilers and pressure vessels

4.8 Corrosion test

4.8.1 When intergranular corrosion testing is required for rolled steels for boilers and pressure vessels, the test shall be carried out according to the requirements in *Ch 2, 9.1 Intergranular corrosion test*. In case requirements for pitting corrosion resistance are specified, the appropriate corrosion tests shall be carried out in accordance with *Ch 2, 9.2 Pitting corrosion test*.

■ *Section 6*
Carbon-manganese and nickel alloy steels for low temperature service

6.1 Scope

6.1.2 The requirements of this Section are also applicable for other types of pressure vessels where the use of steels with guaranteed impact properties at ~~low temperatures~~ minimum design temperature lower than 0°C is required.

6.1.5 The requirements for selection of grades and thickness for plates for appropriate minimum design temperatures are given in the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* and the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels*, for applications defined in *Ch 3, 6.1 Scope 6.1.1* and *Ch 3, 6.1 Scope 6.1.2*.

■ *Section 7*
Austenitic and duplex stainless steels

7.6 Corrosion tests

7.6.1 For certain specific applications such as storage tanks for chemicals, it may be necessary to demonstrate that the material used is not susceptible to corrosion resulting from precipitation of deleterious phases such as the grain boundary precipitation of chromium-rich carbides.

7.6.3 Unless otherwise agreed or required for a particular chemical cargo, an intergranular corrosion test for austenitic stainless steels and a pitting corrosion test for duplex stainless steels are to be performed. The testing procedures are given in~~, *see*~~ *Ch 2, 9 Corrosion tests* ~~and, for the pitting corrosion test, unless otherwise specified, the test temperatures shall be 20°C for S31803 and 30°C for S32750~~.

Chapter 4
Steel Castings

■ *Section 8*
Stainless steel castings

8.5 Corrosion tests

8.5.2 Where corrosive conditions are anticipated in service, for duplex stainless grades pitting corrosion tests are required in accordance with *Ch 2, 9.2 Pitting corrosion test*. ~~For UNS J 92205 the test temperature is to be 20°C.~~

■ *Section 10*
Steel castings for special marine application

10.1 Goal-based framework

10.1.1 The purpose of this Section is to present a goal-based approach to the requirements for high strength steel castings for special marine applications not covered elsewhere in these Rules. Whilst the primary intent of the application of the material listed herein is for the construction of submersible craft (including their critical components, products and systems), intended for human occupancy, use and application of this material for other constructions may be specially considered within the scope of the goal-based framework.

10.1.2 The goals, functional requirements and performance requirements listed herein relate to the manufacture and testing of the applicable base materials.

10.1.3 In addition to this goal-based framework, the relevant requirements of these Rules are to be complied with to achieve certification. In order to satisfy the goal-based framework in this Chapter, it is also necessary to comply with the applicable Rules related to materials, manufacture, testing, survey and classification.

10.1.4 The list of goals is as follows:

(a) The material shall withstand the applied design loads and integrity requirements for minimising the likelihood of loss of the structure due to failure.
(b) The material for components, products and systems shall minimise the hazard to persons, assets or the environment in any foreseeable operating conditions.

10.1.5 The list of functional requirements (FR) is as follows:

(a) The material shall be manufactured and finished so as to provide assurance that the appropriate quality and mechanical property requirements are achieved.
(b) The material shall be weldable.
(c) The material shall function in a safe and acceptable manner, for compliance with manufacturing and design criteria.

10.1.6 The list of performance requirements (PR) is as follows:

(a) The material shall have the mechanical properties for Material Class (Special Application Steel Castings) as specified in *Table 4.10.1 Essential mechanical properties for SASC,* and any other project requirements.
(b) The material shall have the chemical composition for the appropriate LR Material, as specified in *Table 4.10.2 Chemical composition for SASC* and *Table 4.10.3 Allowable Variation in chemical composition of the product from the ladle for SASC*, and any other project requirements.
(c) The material shall demonstrate the ability to:
    (i) Withstand explosive loading, when applicable.
    (ii) Meet suitable toughness requirements as required by the application and by the specified testing regime.
    (iii) Withstand tensile loads under the specified operating conditions and meet the requirements of a specified testing regime.

(iv) Be suitably ductile for loads under the specified operating conditions and meet the requirements of a specified testing regime.

(d) Meet specified identification, dimensional and quality requirements.

(e) All castings shall be in the quenched and tempered supply condition or within the heat treatment parameters according to the approved manufacturing specification in order to achieve the required mechanical properties.

(f) The weldability of the material shall be confirmed by either an evidence-based regime according to a recognised method or by a performance-based regime, agreed with LR. The maximum CEV value shall be as specified in *Ch 4, 10.4 Manufacture and chemical composition 10.4.4*.

(g) Castings of the Material Class Special Application Steel Castings (SASC) are to be categorised as class I, II or III according to their service condition as described in *Table 4.10.4 Special application steel casting classification*.

It shall be incumbent on designers to correctly classify the castings as appropriate to their application.

Table 4.10.1 Essential mechanical properties for SASC

0,2 per cent Proof Strength (MPa)^{See} Note	Elongation (%)	Reduction of area (%)	Charpy V-notch impact test	
			Test temperature, ^{0}C	Average Energy, J
550 Min	16 Min	35 Min	-20	- For three test pieces, the energy is to be not less than 100 J - no single value is to be less than 82 J.
Note: The tensile strength shall be recorded and is to be such that the ratio 0,2% proof strength to tensile strength is not greater than 0,88.				

Table 4.10.2 Chemical composition for SASC

Element	**Weight per cent**	
	Minimum	**Maximum**
Carbon	–	0,20
Manganese	0,55	0,75
Phosphorus (*see* Note 1)	–	0,010
Sulphur (*see* Note 1) Silicon	–	0,010
Nickel	0,20	0,50
Chromium	2,50	3,25
Molybdenum	1,35	1,65
Aluminium	0,30	0,60
	0,01	0,03
Residual Elements		
Titanium	–	0,02
Vanadium	–	0,03
Copper	–	0,20
Arsenic	–	0,03
Antimony	–	0,010
Lead	–	0,005
Nitrogen (*see* Note 2)	–	0,010
Tin	–	0,02
Cobalt	–	0,030
Zirconium	–	0,025

Note 1: The percentage of phosphorus and sulphur together is not to exceed 0,018%. Where castings are specified as subject to stress relief, the recommended maximum phosphorus content is 0,008%. Where castings are to be electron beam welded, the sulphur and phosphorous content is not to exceed 0,006% each.

Note 2: The nitrogen content is to be as low as possible and must not exceed 0,010%, but refer also to *Ch 4, 10.4 Manufacture and chemical composition 10.4.1*.

Table 4.10.3 Allowable variation in chemical composition of the product from the ladle for SASC

Element	Variations (% by Weight)	
	Under the lower limit	Over the upper limit
Manganese	0,05	0,05
Phosphorus and Sulphur (See Note)	-	0,003
Silicon	0,03	0,03
Nickel	0,07	0,07
Chromium	0,06	0,06
Molybdenum	0,03	0,03
Note: On product check analysis, the percentage of phosphorus and sulphur together is not to exceed 0,018%.		

Table 4.10.4 Special application steel casting classification

Application Class	Service Condition
Class I	A casting for which its failure would lead to uncontrollable flooding, total vessel immobilisation, or harm to personnel. Class I castings have very high standards of inspection and acceptance and are intended for use in critical parts of the vessel.
Class II	A casting for which its failure would lead to severe but controllable flooding, or the serious disruption of propulsion machinery or its attendant auxiliaries, including generators.
Class III	All other castings.

10.2 LR accepted solutions for Special Application Steel Castings (SASC)

10.2.1 Provision is made in this Section for weldable steel castings intended for use in special marine applications which are not covered elsewhere in this Chapter.

10.2.2 An accepted solution for satisfactorily meeting the goal-based framework is specified in sub-Sections *Ch 4, 10.3 General requirements* to *Ch 4, 10.14 Welding requirements* of this Section.

10.2.3 The application, in entirety, of the prescriptive content in this Section (including any external references) is considered to meet the listed goals.

10.2.4 Alternative proposals for meeting the goal-based framework in *Ch 4, 10.1 Goal-based framework* will be specially considered.

10.2.5 The requirements presented herein represent an accepted material solution to meet the requirements of steel castings for special marine applications, of which Q1(N) grade casting is an example.

10.3 General requirements

10.3.1 In addition to the requirements of this sub-Section, fulfilment of an accepted solution also requires compliance with the relevant Sections of these Rules, specifically:

- *Ch 1 General Requirements*,

- *Ch 2 Testing Procedures for Metallic Materials*, and
- *Ch 4, 1 General requirements*.

regarding approval and manufacture, testing, inspection and general requirements for materials.

10.4 Manufacture and chemical composition

10.4.1 Castings are to be produced from steel which has been made by the basic electric furnace process and vacuum treated, or by other approved process routes. The steel is to be fully killed using aluminium fine grain practice with a minimum content of 0,015 per cent and greater than twice the percentage of nitrogen. As to the location of the casting's identification markings prior to manufacture, reference is to be made to *Ch 4, 10.10 Identification of materials 10.10.2*.

10.4.2 Each cast is to be analysed using ladle samples and for product analysis, one chemical analysis per test coupon shall be undertaken.

10.4.3 The ladle analysis is to conform to the chemical composition stated in *Table 4.10.2 Chemical composition for SASC*. On check analysis of the product, the acceptable variations in composition of product from ladle composition shall not exceed that stated in *Table 4.10.3 Allowable Variation in chemical composition of the product from the ladle for SASC*. For elements where no product analysis variation is specified in *Table 4.10.3 Allowable Variation in chemical composition of the product from the ladle for SASC*, the limits for check analysis and ladle analysis are to comply with the limits in *Table 4.10.2 Chemical composition for SASC*.

10.4.4 The Carbon Equivalent Value (CEV) is to be calculated in accordance with the formula:

$$\mathrm{CEV} = C + \frac{Mn}{6} + \frac{Ni}{40} + \frac{Cr}{5} + \frac{Mo}{4} + \frac{Si}{24} + \frac{V}{15}$$

The target CEV in production is 0,75 and is not to exceed 0,80.

Note This CEV formula is only to be used for the LR SASC. Other references to CEV formulae within LR Rules are not applicable to SASC. Similarly, this formula shall not be used to determine CEV for any other steel or product contained in other Rules, Chapters or Sections not related specifically to SASC.

10.5 Heat treatment

10.5.1 The castings are to be supplied in the quenched and tempered heat treatment condition. The castings are to be subjected, as necessary, to an appropriate refining treatment before being heated for water quenching or spray quenching and tempering. The manufacturer is to determine the detailed heat treatment to produce castings to meet the requirements of this specification. A suitable austenitising temperature, not exceeding 955°C, is to be selected.

10.5.2 The tempering treatment is to be carried out within a temperature range of 600°C to 675°C. Water quenching from the tempering temperature is mandatory. When necessary, double tempering is permitted. Those restrictions specified for single tempering also apply to double tempering.

10.5.3 Attachment of thermocouples to the steel castings and the furnace operations shall be as required by *Ch 4, 1.5 Heat treatment 1.5.2* and *Ch 4, 1.5 Heat treatment 1.5.3*. The manufacturer shall also demonstrate to the satisfaction of the Project Authority and the LR Surveyor, that casting heating occurs in a controlled manner and that under equilibrium conditions the castings temperature is within 10°C of the control setting.

10.5.4 Test blocks are to accompany the casting or castings they represent through all heat treatment cycles. It is essential that such test material remains an integral part of the parent casting or castings. Should this prove impractical then the test blocks are to be securely attached to the castings they represent.

10.6 Cleanliness

10.6.1 The manufacturer shall keep the steel as free as possible from non-metallic inclusions subject to the requirements of *Ch 4, 10.13 Non-Destructive Examination - Assessment of defects*.

10.7 Cleaning of castings

10.7.1 Castings must have feeder heads and in-gates removed and must be thoroughly cleaned. All sand, scale, fins and excessive rough spots shall be removed.

10.7.2 Padding added by the foundry to provide directional solidification must be removed. When heads, gates and padding are removed by gas cutting or scarfing, the removal is to be performed before the final heat treatment and in such a manner as not to impair the structural/dimensional configuration of the casting.

10.7.3 When unacceptable defects are found in the castings, these are to be removed by the methods (or a combination of the methods) specified in *Ch 4, 1.11 Rectification and dressing of castings*.

10.7.4 All gas and arc cut surfaces which, in the final structure, have not been incorporated into a welded joint and which will be exposed to sea water in service, shall have the heat affected zone caused by the cutting removed by grinding or machining.

10.8 Mechanical tests

10.8.1 Sampling for mechanical test: A sufficient number of test blocks shall be provided, including the provision of spare material should the need for re-tests or re-heat treatment retests arise. The test blocks must be cast as an integral part of the casting or batch of castings from the same melt. Adequate measures are to be taken to ensure test block soundness. The use of chill moulds is prohibited.

10.8.2 Test block size: The size of each test block must be in proportion to the thickness (*T*) of the casting as indicated in *Table 4.10.5 Test Block Sizes for Castings*. Two sets of test blocks are required in a mixed batch of castings for heat treatment. One set of blocks will represent the maximum (*T*) of the largest casting and one set the maximum (*T*) of the smallest casting in the batch. Where a batch consists of identical castings one set of test blocks will suffice. The recommended dimensions of the test blocks are shown in *Table 4.10.5 Test Block Sizes for Castings*.

Table 4.10.5 Test Block Sizes for Castings

Thickness (T)	Test Block Dimensions
Up to 50 mm	T x 200 mm x 200 mm (subject to minimum T of 25 mm)
Over 50 mm	T x 250 mm x 250 mm

Note. The dimension (T) is defined as the diameter of the largest circle that can be inscribed in any cross section of the as-heat-treated casting unless specified otherwise by the Project Authority, contract or order. The dimensions specified are the minimum. The length and width may be increased to secure a practical test block size for the preparation of test specimens.

The terms large and small castings are defined by the respective (T) of each.

10.8.3 A heat treatment batch or lot is defined as that batch or lot of castings produced from the same melt and heat treated together. Where castings from more than one melt are to be heat treated together, then action must be taken to ensure that the identity of all castings can be readily traced back to their respective melts. Additional test blocks are also to be provided under the requirement, as if that batch of castings from each melt were being heat treated as separate batches.

10.8.4 Tensile test pieces and tensile testing method shall be in accordance with ISO 6892-1. Where material thickness permits, the test pieces should be of a circular cross-section with a cross-sectional area of 200 mm^2. Where the material thickness does not permit this size, the test piece should be the largest possible in accordance with ISO 6892-1. All test pieces shall have a gauge length equal to $5,65\sqrt{S_0}$ (where S_0 is the cross-sectional area of the test piece). The test pieces are to be taken at $T/4$ (one quarter of thickness) below the heat-treated surface of the test block, where T is the block thickness.

10.8.5 Three Charpy V notch tests are to be taken from each test block in the heat treatment batch. The test pieces are to be taken at $T/4$ (one quarter of thickness) or 25 mm, whichever is less, below the as heat-treated surface of the test block. The length of the notch must be perpendicular to the as-cast surface.

10.8.6 The Charpy V notch test pieces are to be prepared and tested in accordance with ISO 148-1. The test specimens are to be machined to the dimensions and tolerances of the standard test piece given in *Ch 2, 3 Impact tests, Table 2.3.1 Dimensions and tolerances for Charpy V-notch impact test specimens* and are to be carefully checked for dimensional accuracy.

10.9 Mechanical retests

10.9.1 If any test piece fails the mechanical tests, two further test pieces from the same test block may be selected for retest. The castings will be deemed acceptable if these retests satisfy the specified requirements. The supplier has the right to re-heat treat the casting or castings and is to include sufficient test material from the same melt for retest. After re-heat treatment the casting or castings are to be subjected in full to the tests and examinations specified.

10.9.2 If any test piece fails after the second re-heat treatment the entire batch, represented by these tests, is to be rejected.

10.9.3 All critical dimensions and tolerances must be met even if there is any wastage due to decarburisation and due to the re-heat treatment processes.

10.10 Identification of materials

10.10.1 To provide identification and traceability, all castings must be permanently marked with:

- Special Application Steel Castings and manufacturer's numbers which, must be sufficient to identify each casting unambiguously to its history and all test documentation to enable full traceability.
- Any other information required by the contract or order. In particular, castings are to be identified according to any project-specific requirements in addition to LR identification requirements.

10.10.2 All identification and other marks shall be located to ensure that they are not machined off in finishing, and in a lightly stressed area of the casting. Such locations must be indicated on the design drawings.

10.11 Additional approval testing

10.11.1 The project specification will state the specific dynamic fracture toughness testing procedure or explosion test, as applicable. Where required, the material shall meet the toughness requirements as required by the specified testing regime.

10.11.2 The project specification will state any additional tests for manufacturer approval, and the performance criteria and properties required.

10.11.3 The project requirements may specify appropriate and additional specialised testing for manufacturer approval.

10.12 Visual and Non-Destructive Examination requirements

10.12.1 Selection and delineation of regions: The designer shall provide reference diagrams for Class I and II castings showing the regions to be examined by Non-Destructive Examination. These regions shall be designated as Critical Test Regions and Test Regions in accordance with the following principles in *Table 4.10.6 Designation of regions*.

Table 4.10.6 Designation of regions

Region	Definition *See Notes 1 & 2*
Critical Test Region	Critical Test Regions shall be the regions of Class I castings that may be highly stressed as a result of operating conditions, taking into account whether or not the casting is resiliently mounted
Test Region	Test Regions shall be all regions of Class I castings not designated as a Critical Test Region and the regions of Class II castings that may be highly stressed as a result of operating conditions, taking into account whether or not the casting is resiliently mounted
Non-designated region	Non-designated regions shall be all regions of Class II castings not designated as a Test Region and all regions of Class III castings.
Note *1*: Exceptionally, certain areas of a Class I casting shall not be designated, e.g. division plates in heat exchanger end covers. Note *2*: Where a Class II casting is not highly stressed, the designer shall not designate any region as a Test Region. Sample radiography of the positions as indicated by the designer shall be inspected in accordance with *Ch 1, 5 Non-Destructive Examination*.	

10.12.2 Definition of regions: The extent of Critical Test Regions and Test Regions shall be determined by the designer and shall be shown dimensionally on the reference diagram. Datums for these dimensions shall be flange facings, cover flanges, valve seats, etc.

10.12.3 The examples in *Figure 4.10.1 Flange to plain neck* and *Figure 4.10.2 Plain tee junction* are given for typical junctions subject to high working and/or shock stress and are for guidance only.

10.12.4 The actual values for any casting shall be detailed by the designer so that relevant areas are covered to ensure all the stressed regions are inspected.

10.12.5 Critical Test Regions and Test Regions shall be clearly marked on the reference diagrams. The preferred method of marking shall be as follows:

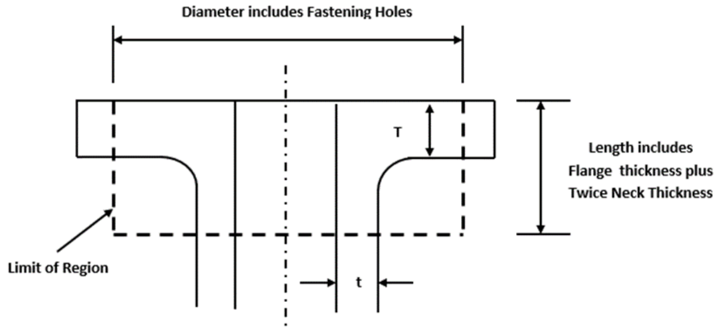

Figure 4.10.1 Flange to plain neck

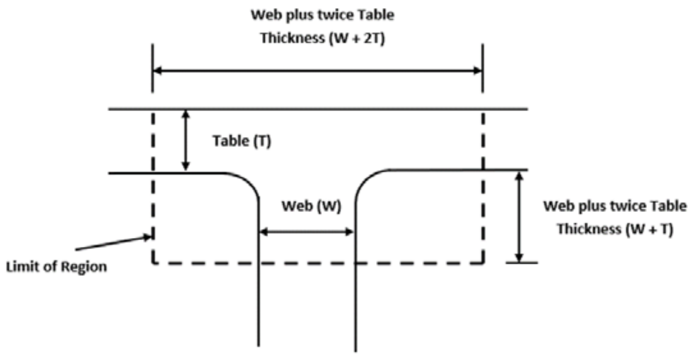

Figure 4.10.2 Plain tee junction

10.12.6 Alternative methods of marking may be acceptable, provided the method clearly distinguishes between Critical Test Regions and Test Regions and the alternative method of marking is defined on the reference diagram.

10.12.7 Where colours are used to indicate Critical Test Regions and Test Regions, RED shall be used for Critical Test Regions and BLUE shall be used for Test Regions.

10.12.8 Dimensional check: Dimensional checks of castings shall be in accordance with *Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.4* and include section thickness measurement.

10.12.9 Visual inspection: All castings shall be 100 per cent visually inspected in accordance with *Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.5*. Visual inspections can be supplemented by means of optical equipment where deemed necessary.

10.12.10 Magnetic particle and liquid penetrant inspection: All external, and where possible internal surfaces of Class I and Class II castings, shall be fully inspected preferably by magnetic particle inspection. In the event internal surfaces cannot be accessed for inspection, then such limitations shall be declared on the inspection reports. If access does not allow magnetic particle inspection, then liquid penetrant methods may be used in accordance with the requirements of *Ch 4, 1.7 Visual and surface Non-Destructive Examination*. Inspection shall be carried out in accordance with the requirements of *Ch 1, 5 Non-Destructive Examination*.

10.12.11 Radiographic and ultrasonic inspection: All Critical Test Regions and all Test Regions shall be fully inspected by radiographic or ultrasonic inspection in accordance with the requirements of *Ch 1, 5 Non-Destructive Examination* and *Ch 4, 1.8 Volumetric Non-Destructive Examination*. The suitability for ultrasonic inspection shall be assessed in accordance with the requirements of ISO 12680-1.

10.12.12 Where it is proposed to inspect designated areas by ultrasonic inspection the procedure shall be approved in accordance with the requirements of *Ch 1, 5 Non-Destructive Examination*. Unless otherwise agreed, the ultrasonic inspection of castings shall be supplemented by radiography of selected areas nominated by the Project Authority and represent a minimum of 10 per cent of the total area examined by ultrasonic inspection.

10.12.13 Radiographic inspection of non-designated regions shall be done on a sample basis. Examination by radiography may be specified by contract or drawings on a sample basis to establish that a satisfactory general quality of product is being supplied. Typical examples are as follows:

(a) Lowly stressed Class II castings.;
(b) Sample positions on large Class II or Class III castings;
(c) Batch supply of Class III castings.

10.13 Non-Destructive Examination - Assessment of defects

10.13.1 Defects such as cracks, hot tears, cold shuts and lack of fusion, as appropriate, are not acceptable in the casting or any weld repairs undertaken. Defect severity for all other defects shall be assessed in terms of the reduction in section thickness and the area of the defect.

10.13.2 Acceptance standards for dimensions: Castings shall be within the dimensional tolerances stated in contract drawings. Deviations from the contract drawings section thickness shall be acceptable within the following limits in *Table 4.10.7 Dimensional acceptance criteria for section thickness tolerances for SASC.*

Table 4.10.7 Dimensional acceptance criteria for section thickness tolerances for SASC

Section Thickness Tolerances		
Section Thicknesses		Tolerances
Case 1	≤50 mm	+ 10%
	>50 mm	+ 5 mm
Case 2	≤50 mm	- 10%
	>50 mm	- 5 mm

For Case 2 to apply the following must also apply:

a. The reduced section thickness shall be free from sub-surface defects in Critical Test Regions and test regions, or shall be in accordance with the requirements of the sub-surface defects clause for non-designated regions; and

b. The total area of reduced thickness, including that which may arise through the blending out of surface defects, shall not exceed 10% of any designated or non-designated region. *See* Note**.**

Note*:* Unacceptable surface defects may be blended out by a process subject to agreement with LR. Blending out of surface defects shall be used in preference to weld repair whenever possible. The resulting depression shall not reduce the contract drawing section thickness by more than 5 mm for section thickness over 50 mm, or 10% of section thicknesses up to and including 50 mm. The depression sides and ends shall be smoothly blended out by a minimum radius of three times the maximum depth of blending and the edge formed with the surface shall be faired smooth. The remaining section thickness in way of the depression shall be free from sub-surface defects in Critical Test Regions and Test Regions, as revealed by radiography or ultrasonic examinations. The total area subjected to blending, including the area affected by the fairing, shall not exceed 10% of any designated region or 20% of any non-designated region. The complete surface area of the blended depression shall be inspected using a liquid penetrant examination technique.

10.13.3 On visual inspection the finished condition of all surfaces shall be clean and free from cracks or linear defects. Rounded forms of surface indications shall be unacceptable in critical test regions and test regions but may be acceptable in non-designated regions at the discretion of the Project Authority and the LR Surveyor.

10.13.4 Isolated porosity (minimum separation 50 mm) revealed by liquid penetrant or magnetic particle testing shall be acceptable except in areas where sealing of a housing against a running shaft is required, for example pump glands, propeller shaft seals, etc. and in flexible couplings.

10.13.5 Porosity indications revealed by liquid penetrant or magnetic particle inspection shall be acceptable in Critical Test Regions and Test Regions, provided the following applies:

(a) the maximum size of any indication does not exceed 3 mm diameter; and
(b) the sum of the diameters of all indications in an area of 70 x 70 mm does not exceed 24 mm.
(c) Other acceptance criteria may be considered where the project authority has alternative requirements, providing this is at least equivalent to the criteria stated herein.

10.13.6 Liquid penetrant indications: Liquid penetrant indications shall be assessed on bleed-out. However, in order to eliminate variations in technique application, the assessment shall be completed after the following actions:

(a) At the end of the initial technique full development period, the developer shall be wiped off around the indications using a dry lint free cloth or paper.
(b) Fresh developer shall be applied to the area of the indication.

(c) At the end of another full development period the diameter of the bleed-out shall be measured and this figure used to assess any revealed defects in accordance with the above requirements for surface defects.

10.13.7 Assessment of radiography: Reduction in section thickness caused by non-defects shall be assessed by visual comparison with suitable density check films showing the approximate percentage change for the particular radiographic technique, material and thickness range. The NDE contractor shall be responsible for the production of suitable density check films for the particular thickness range inspected and radiographic technique applied.

10.13.8 Sub-surface defects as revealed by radiography: The defect terminology shall be in accordance with a recognised National/International Standard. Cracks, hot tears, cold shuts and cold shuts in castings are not acceptable. Lack of fusion in areas of weld repairs are not acceptable.

10.13.9 Filamentary shrinkage, non-metallic inclusions, sponginess and micro-porosity shall be accepted provided the following conditions apply:

(a) In Critical Test Regions the local reduction in thickness resulting from these defects shall not exceed 5 per cent of the contract drawings section thicknesses and the total defective area shall not exceed 10 per cent of the region.
(b) In Test Regions the local reduction in thickness resulting from these defects shall not exceed 10 per cent of the contract drawings section thicknesses and the total defective area shall not exceed 20 per cent of the region.

10.13.10 Isolated shrinkage cavities, gas holes, airlocks and rounded inclusions shall be acceptable, provided that the local reduction in section thickness resulting from these defects, together with other sub-surface defects, shall not exceed 10 per cent of the contract drawings section thicknesses in Critical Test Regions and 20 per cent in Test Regions.

10.13.11 The results of sample inspections shall not reveal cumulative local reductions in section thickness, resulting from sub-surface defects at any position, of more than 20 per cent of the contract drawings section thickness. The total defective area shall not exceed 20 per cent of the total area of the casting.

10.13.12 Assessment of ultrasonics: The methods that shall be used for the assessment of the severity of defects when using ultrasonic inspection shall form part of the written procedure, which shall be submitted to Project Authority and LR Surveyor for agreement. Supplementary radiography may be specified to identify the nature of the defect.

10.13.13 The assessment of indications as revealed by ultrasonic testing shall be in accordance with the acceptance criteria stated within *Ch 4, 2.6 Acceptance levels for Non-Destructive Examination of castings*, *Table 4.2.6 Ultrasonic Acceptance Criteria for steel castings – Using DGS or DAC system*. Other acceptance criteria may be applied as determined by the project requirements and will be reviewed on a case-by-case basis.

10.13.14 Proximity of individual defects: Defective areas, as defined in *Ch 4, 10.12 Visual and Non-Destructive Examination requirements* and *Ch 4, 10.13 Non-Destructive Examination - Assessment of defects* and discrete as defined in *Ch 4, 10.13 Non-Destructive Examination - Assessment of defects 10.13.10*, shall be separated by at least 2,25 times the contract drawing section thickness of the casting in way of the defect or 1,25 times the length of the larger adjacent defect, whichever is the greater. However, if the distance between the ends of two defects or defective areas is less than either of the above values, they shall be considered as a single defect having an overall length equal to the distance measured between the two extremities of the defects or defective areas.

10.13.15 Non-Destructive Examination of weld repairs: All weld repairs shall be subjected to full re-inspection by the appropriate inspection method and shall be undertaken in accordance with *Ch 4, 1.11 Rectification and dressing of castings*.

10.13.16 Acceptance standards for weld repairs: The acceptance standards for weld repairs shall be in accordance with the requirements of *Ch 4, 1.11 Rectification and dressing of castings 1.11.14*.

10.13.17 Pressure testing: Where pressure tests are required by the Project Authority, each casting shall be pressure tested to the test pressure stated in contract documents. Unless otherwise stated in the Test Specification the test medium shall be water and the test pressure shall be maintained for a minimum of 15 minutes and sufficient to permit a full inspection for leakage. Castings shall be tested in accordance with the requirements of *Ch 4, 1.10 Pressure testing*.

Each casting shall show no evidence of leakage.

10.14 Welding requirements

10.14.1 Rectification of defective castings: The rectification of casting defects is to follow the requirements of *Ch 4. 1.11 Rectification and dressing of castings*, and the following paragraphs. Weld repairs are allowed after quenching and tempering of the casting and completion of mechanical testing. After weld repair, there is to be no heat treatment carried out on the casting other than Post-Weld Heat Treatment.

10.14.2 Welding consumables for weld repair of SASC in general, to be approved in accordance with *Ch 11, 10 Consumables for high strength steel for special marine applications*.

10.14.3 Preheat, is to be as specified for High strength steel – Special Application 1 in *Table 13.10.3 Recommended pre-heat temperature requirements for applicable Material Class Special Applications 1 and 2*. The interpass temperature is to be as specified in *Ch 13, 10.3 General requirements 10.3.10*. Heat input shall be within the limits of the approved WPS.

10.14.4 Post-Weld Heat Treatment: Post-Weld Heat Treatment shall be a minimum of 20°C below the final tempering temperature but not less than 600°C. The time at this temperature shall be one hour per 25 mm of thickness based upon the thickest member in the weldment. The total time in the furnace at temperatures above 250°C shall not exceed 15 hours.

10.14.5 The rate at which the temperature of the weld rises above 250°C is not to exceed 200°C per hour or 200°C/*T* per hour, whichever is the lower (*T* = maximum steel thickness in units of 25 mm).

10.14.6 Accelerated cooling from the post-weld heat treatment temperature shall be carried out. Cooling may be forced air cooling, forced waterspray cooling, or water quench.

10.14.7 Rectification of dimensional defects by welding: The correction of casting dimensions or machining errors may be made by welding provided:

(a) The area of weld deposition shall be restricted to 10 per cent of the surface area of the region in the Critical Test Regions or Test Regions and 20 per cent in non-designated regions. These areas shall be subject to any additional limitations prescribed in *Ch 4, 10.14 Welding requirements 10.14.12*.
(b) For section thickness, 7 mm, and above, weld deposition shall be no greater than 20 per cent of contract drawing thickness or 10 mm, whichever is the least. Where the section thickness is less than 7 mm, weld deposition is not allowed unless the Project Authority and local Surveyor agrees.

10.14.8 Weld build-up exceeding the tolerance on contract drawing section thickness shall be cause for rejection of the casting.

10.14.9 Rectification of surface defect by blending: Shallow grooves or excavations resulting from the removal of defects by blending may be accepted, provided the resulting depression does not reduce the contract drawing section thickness by more than 5 mm for section thickness over 50 mm, or 10 per cent of section thicknesses up to and including 50 mm.

10.14.10 The total area subjected to blending, including the area affected by the fairing, shall not exceed 10 per cent of any Critical Test Region or Test Region or 20 per cent of any non-designated region.

10.14.11 Rectification of surface and sub-surface defects by welding: It is permissible to repair by welding unacceptable surface defects which cannot be rectified within the limits of *Ch 4, 10.14 Welding requirements 10.14.9*, and unacceptable sub-surface defects provided:

(a) The excavation depth in Critical Test Regions and Test Regions does not exceed 50 per cent of the casting thickness.
(b) Any individual repair in Critical Test Regions shall not exceed 10 per cent of the Critical Test Region area containing the defect. Any repair in a Test Region shall not exceed 20 per cent of the Test Region area containing the defect.
(c) The excavation area in Critical Test Regions and Test Regions shall be no more than 20 per cent of the region's surface area, not including flange thicknesses and webs.

10.14.12 Limits on combined weld repairs: The total combined area of weld repairs from all causes (for example, dimensional correction, surface, and sub-surface defects) shall be within the following limits:

(a) Total weld repair area of Class I and Class II castings shall not exceed 10 per cent of the surface area of the casting, excluding flange thicknesses and webs.
(b) The total weld repair area of Class III castings shall not exceed 20 per cent of the surface area of the casting, excluding flange thicknesses and webs.

10.14.13 Impregnation: The impregnation of the casting with a polymer resin to rectify porosity is not acceptable for Class I castings. For Class II and III castings, impregnation is acceptable with the approval of the Project Authority and the local surveyor.

10.14.14 The casting area requiring impregnation shall not exceed 10 per cent of the designated Test Region area containing the defect in Class II castings or the total area pressure tested in non-designated regions in Class II and III castings.

10.14.15 Welding documentation: In addition to the requirements stated in *Ch 4, 1.11 Rectification and dressing of castings 1.11.16*, the manufacturer shall retain in their records for each weld repair:

(a) Approved welder qualifications;
(b) Welding consumable certificate;
(c) NDE record of excavation; and
(d) NDE record of completed repairs.

Chapter 5
Steel Forgings

■ *Section 9*
Stainless steel forgings

9.7 Corrosion tests

9.7.2 Where corrosive conditions are anticipated in service, for duplex stainless grades pitting corrosion tests are required in accordance with *Ch 2, 9.2 Pitting corrosion test*. ~~Unless otherwise specified, the test temperatures shall be 20°C for S31803 and 30°C for S32750.~~

Chapter 6
Steel Pipes and Tubes

■ *Section 5*
Stainless steel pressure pipes

5.5 Corrosion tests

5.5.1 For materials used for piping systems for chemicals, corrosion tests are to be carried out on one per cent of the number of pipes in each batch, with a minimum of one pipe. For austenitic stainless steels this ~~should~~ shall be an ~~intercrystalline~~ intergranular corrosion test (*see Ch 2, 9.1 Intergranular corrosion test*) and for duplex stainless steels this ~~should~~shall be a pitting corrosion test (*see Ch 2, 9.2 Pitting corrosion test*). ~~For the latter, the test temperatures shall be 20°C for S31803 and 30°C for S32750.~~

Existing paragraphs 5.5.2 and 5.5.3 have been deleted.

~~5.5.4~~5.5.2 After immersion, the full cross-section test specimens are to be subjected to a flattening test in accordance with the requirements of ~~*Ch 2 Testing Procedures for Metallic Materials*~~*Ch 2, 4.2 Flattening tests*. The strip test specimens are to be subjected to a bend test ~~through 90° over a mandrel of diameter equal to twice the thickness of the test specimen~~ in accordance with prescribed practices in *Ch 2, 9.1 Intergranular corrosion test*.

Chapter 8
Aluminium Alloys

■ *Section 1*
Plates, bars and sections

1.2 Manufacture

1.2.3 All melts are to be suitably degassed prior to casting such that the ~~aim~~ hydrogen content is demonstrated to be less than 0,20 ml per 100 g.

Chapter 10
Equipment for Mooring and Anchoring

■ *Section 1*
Anchors

1.10 Proof test of anchors

1.10.1 Anchors are to be tested in the presence of the Surveyor at a proving establishment recognised by LR.~~ A list ~~The names of recognised proving establishments~~ is~~ are published ~~separately by LR~~ in the LR Approvals client portal (www.lr.org/en/lr-approvals). In addition to the requirements stated in this Chapter, attention must be given to any relevant ~~statutory requirements ~~Statutory Requirements of the National Authority of the country in which the ship or mobile offshore unit is to be registered.

■ *Section 2*
Stud link chain cables for ships

2.9 Testing of completed chain cables

2.9.2 All chain cables are to be tested in the presence of a Surveyor~~,~~ at a proving establishment recognised by LR. ~~A list~~ The names of recognised proving establishments~~ is~~ are published ~~separately by LR~~ in the LR Approvals client portal (www.lr.org/en/lr-approvals). In addition to the requirements stated in this Chapter, attention must be given to any relevant ~~statutory requirements~~ Statutory Requirements of the National Authority of the country in which the ship is to be registered.

■ *Section 3*
Offshore ~~Mooring~~ mooring chain cables

3.6 Proof load tests and ~~non-destructive examination ~~Non-Destructive Examination

3.6.1 The entire length of chain cable is to be subjected to a proof loading test in the presence of a Surveyor at a ~~P~~proving ~~E~~establishment recognised by LR. ~~A list ~~The names of recognised ~~P~~proving ~~E~~establishments~~ is~~ are published in the ~~Class Direct section of LR's website, http://www.lr.org~~ LR Approvals client portal (www.lr.org/en/lr-approvals). The chain cable is to withstand the load given ~~in *Ch 10, 3.6 Proof load tests and non-destructive examination 3.6.1*~~ in *Ch 10, 3.6 Proof load tests and Non-Destructive Examination 3.6.1* for the appropriate grade and size of cable.

■ *Section 4*
Fittings for offshore mooring chain

4.4 Proof and break load tests

4.4.1 All chain cable fittings, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see Table 10.3.1 Test loads for mooring chain cables*. Prior to this test, the fittings are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection. The fittings for offshore mooring chains are to be tested in the presence of a Surveyor at a proving establishment recognised by LR. The names of recognised proving establishments are published in the LR Approvals client portal (www.lr.org/en/lr-approvals).

■ *Section 5*
Short link chain cables

5.4 Testing and inspection of chain cables

5.4.1 All chain cables of 12,5 mm diameter and above, and all steering chains irrespective of diameter, are to be tested in the presence of a Surveyor at a proving establishment recognised by LR. ~~A list~~The names of recognised proving establishments~~ is~~ are published ~~by~~in the LR Approvals client portal (www.lr.org/en/lr-approvals). In addition to the requirements stated in this Chapter, attention is to be given to any relevant ~~statutory requirements~~ Statutory Requirements of the National Authority of the country in which the ship or other marine structure is to be registered.

■ *Section 6*

Steel wire ropes

6.1 Scope

6.1.1 Provision is made in this Section for the requirements for the manufacture, testing and certification of steel wire ropes intended to be used for general marine purposes, as well as permanent anchoring, mooring and marine lifting applications.

6.2 General requirements

6.2.1 For general marine purposes, such as stream wires, towlines and ship mooring lines, ~~the construction is to be in accordance with Table 10.6.1 Recommended rope construction~~ the construction of steel wire ropes is to be in accordance with ISO 2408, or an equivalent standard acceptable to LR. The construction, diameter and strength of steel wire ropes for permanent offshore applications, such as mooring, anchoring and lifting, are covered by other LR Rules. Alternative applications of steel wire ropes may be accepted, subject to special consideration.

6.2.2 The manufacturer's ~~plant~~ works and method of production are to be approved by LR.~~ A list approved ~~Approved manufacturers of steel wire ropes ~~is published annually in the *List of Approved Manufacturers of Materials* ~~are published in the LR Approvals client portal (www.lr.org/en/lr-approvals).

~~Table 10.6.1 Recommended rope construction~~ *(this table is to be deleted)*

~~Purpose~~	~~Construction of rope~~			~~Construction of strands~~
	~~Strands~~	~~Wires~~	~~Core~~	
~~Stream wires, towlines and mooring lines~~	~~6~~	~~24~~	~~Fibre~~	~~15 over 9 over fibre core~~
	~~6~~	~~37~~	~~Fibre~~	~~18 over 12 over 6 over 1~~
	~~6~~	~~26~~	~~Fibre~~	~~10 over (5 + 5) over 5 over 1~~
	~~6~~	~~31~~	~~Fibre~~	~~12 over (6 + 6) over 6 over 1~~
	~~6~~	~~36~~	~~Fibre~~	~~14 over (7 + 7) over 7 over 1~~
	~~6~~	~~41~~	~~Fibre~~	~~16 over (8 + 8) over 8 over 1~~
	~~6~~	~~30~~	~~Fibre~~	~~18 over 12 over fibre core~~
~~Towlines and mooring lines used in association with mooring winches~~	~~6~~	~~31~~	~~7 x 7 wire rope~~	~~12 over (6 + 6) over 6 over 1~~
	~~6~~	~~36~~	~~7 x 7 wire rope~~	~~14 over (7 + 7) over 7 over 1~~
	~~6~~	~~41~~	~~7 x 7 wire rope~~	~~16 over (8 + 8) over 8 over 1~~

6.2.4 For higher tensile strength grades, where the nominal rope grade exceeds 1960 (*see Table 10.6.1 Rope grade and range of wire tensile strength grades*), the manufacturer shall consider the potential effects of strain ageing of steel wire ropes throughout their service life, which could result in a reduction of the actual breaking load over time and reduced ductility. The manufacturer shall take appropriate precautions to reduce the effects of this phenomenon. Such precautionary measures shall be based on their experience and on data gained from a variety of factors, including, but not limited to:

(a) Rope design consideration e.g. the reason for rope construction design selection and any research related to reduce strain age issues during the design stage.
(b) Mechanical processes during manufacturing, e.g. wire drawing, stranding and lay up configuration, closing, compacting, and other applicable manufacturing processes.
(c) Thermal and coating processes, e.g. galvanisation, plastic coated or filled steel wire rope, temperature control during the wire drawing process, and other related processes.
(d) Testing regimes, e.g. artificial ageing tests as well as comparison of torsion test results for compacted wire with post-spin and pre-spin results.
(e) Historical/in-service application data of these steel wire ropes, e.g. breaking loads over time (including condition monitoring data).
(f) Storage, handling and transportation (and associated temperature and humidity effects).

6.2.5 Measures to address the factors described in *Ch 10, 6.2 General requirements 6.2.4* shall be considered between the manufacturer and purchaser based upon the intended application. Any measures that highlight the need for specific storage, handling, or transportation requirements, including any associated environmental precautions, shall be documented and communicated to the purchaser and relevant parties in the supply chain.

6.3 Steel wire for ropes

6.3.2 For all ropes, the specified minimum tensile strength of the wire is to ~~be 1420, 1570, 1770 or 1960 N/mm2~~. ~~The specified minimum tensile strength of the wire is the designated grade for the rope, unless otherwise defined by the purchaser's specification. The actual tensile strength of the wire is not to exceed 120 per cent of the specified minimum tensile strength~~ meet the requirements of *Table 10.6.1 Rope grade and range of wire tensile strength*.

6.3.3 The variation of tensile strength of individual wires for each grade is to be in accordance with *Table 10.6.2 Variations in wire tensile strength*.

Table 10.6.1 Rope grade and range of wire tensile strength

Rope grade (nominal) (*see* Note)	Range of wire tensile strength, N/mm^2
1570	1370 to 1770
1770	1570 to 1960
1960	1770 to 2160
2160	1960 to 2360
Note. Other intermediate rope grades may be supplied by agreement between the purchaser and the manufacturer	

Table 10.6.2 Variations in wire tensile strength

Nominal diameter of individual wire, *d*, mm	Variation in wire tensile strength above the lower range value (as specified in Table 10.6.1) N/mm^2
$0{,}2 \leq d < 0{,}5$	390
$0{,}5 \leq d < 1{,}0$	350
$1{,}0 \leq d < 1{,}5$	320
$1{,}5 \leq d < 2{,}0$	290
$2{,}0 \leq d < 3{,}5$	260
$3{,}5 \leq d < 7{,}0$	250

6.3.4 Subject to special consideration by LR, rope grades higher than those given in *Table 10.6.1 Rope grade and range of wire tensile strength* may be considered. For these proposed higher grades, the manufacturer shall, as a minimum, consider the potential effects of strain ageing (as described in *Ch 10, 6.2 General requirements, 6.2.4* and *Ch 10, 6.2 General requirements 6.2.5*) and prepare a technical justification identifying precautionary measures or any other identified special measures for mitigating the effects of strain ageing.

Existing paragraphs 6.3.3 to 6.3.6 have been renumbered 6.3.5 to 6.3.8.

~~6.3.7~~ 6.3.9 Torsion tests are to be carried out~~ on the wire by causing one or both of the securing vices to be revolved until fracture occurs (a tensile load not exceeding two per cent of the breaking load of the wire may be applied to keep the wire stretched)~~ in accordance with ISO 7800.

~~6.3.8~~ 6.3.10 ~~The uncoated wire is to withstand, without fracture, the number of complete twists given for Grades 1 or 3 in *Table 10.6.2 Torsion test*.~~ The uncoated and galvanised wire is to withstand, without fracture, the minimum number of torsions as specified in EN 10264-2 or EN 10264-3, as applicable for a given nominal diameter, tensile strength grade (of wire) and surface condition.

~~6.3.9 The galvanised wire is to withstand, without fracture, the number of complete twists given in the specification, as agreed with the purchaser and LR. In the absence of a suitable specification, the results are to comply with *Table 10.6.2 Torsion test*.~~

~~6.3.10~~ 6.3.11 ~~Hot dipped galvanised steel wire is to be used for the manufacture of ropes for marine applications. Depending upon the application, the coating may comply with any of the grades in *Table 10.6.3 Zinc coating*. Grades 1 and 2 are heavy coatings. Grade 3 is the minimum coating weight where the galvanising is carried out prior to final wire drawing. Uncoated wire may be considered for approved applications.~~ Hot dipped galvanised steel wire is to be used for the manufacture of ropes for marine applications. Depending upon the application, the coating should comply with the applicable Class A or Class B requirements, as per EN 10244-2. Other coating requirements to an alternative class or standard may be specially considered. Uncoated wire may be considered for approved applications.

Existing paragraphs 6.3.11 to 6.3.13 have been renumbered 6.3.12 to 6.3.14.

~~6.3.14~~ 6.3.15 ~~The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for 10 complete turns. The ratio between the diameter of the mandrel and that of the wire is to be as in~~ ~~*Table 10.6.4 Wrap test for adhesion of coating*~~. ~~After wrapping on the appropriate mandrel, the zinc coating is to have neither flaked nor cracked to such an extent that any zinc can be removed by rubbing with a cloth.~~ The adhesion of the coating is to be tested in accordance with ISO 7802. The relationship between the diameter of the coiling mandrel and the diameter of the wire shall be in accordance with EN 10244-1. In the case of a wire diameter greater than 7,5 mm, the wrapping test shall be replaced by a bending test in which the wire is bent to least 90° around the mandrel. During the test, the coating shall adhere to the steel when subjected to the conditions of wrapping test for adherence. It shall not crack or split to such an extent that slivers of coating can be removed by simply rubbing with the bare fingers. The loosening or detachment during testing of small particles of zinc resulting from mechanical polishing of the surface of the zinc or zinc alloy coating shall not be a cause for rejection.

~~Table 10.6.2 Torsion test~~ *(this table to be deleted)*

~~Diameter coated wire mm~~	~~Minimum number of twists~~						
	~~Grade 2~~		~~Grade 1 or 3~~				
	~~Minimum strength N/mm²~~		~~Minimum strength N/mm²~~				
	~~1570~~	~~1770~~	~~1420~~	~~1570~~	~~1770~~	~~1960~~	
~~<1,3~~	~~19~~	~~18~~	~~29~~	~~26~~	~~23~~	~~23~~	
~~≥1,3 <2,3~~	~~18~~	~~17~~	~~26~~	~~24~~	~~21~~	~~21~~	
~~≥2,3 <3,0~~	~~16~~	~~14~~	~~24~~	~~22~~	~~—~~	~~19~~	
~~≥3,0 <4,0~~	~~12~~	~~10~~	~~20~~	~~18~~	~~—~~	~~17~~	
~~≥4,0 <4,6~~	~~—~~	~~—~~	~~18~~	~~16~~	~~—~~	~~—~~	
~~≥4,6 <5,0~~	~~—~~	~~—~~	~~16~~	~~14~~	~~—~~	~~—~~	
~~≥5,0 <6,0~~	~~—~~	~~—~~	~~14~~	~~11~~	~~—~~	~~—~~	
~~Note The minimum test length is 100*d* or 300 mm, where *d* is the wire diameter.~~							

~~Table 10.6.3 Zinc coating~~ *(this table to be deleted)*

~~Diameter of coated wire mm~~	~~Zinc coating, minimum g/m²~~		
	~~Grade 1~~	~~Grade 2~~	~~Grade 3~~
~~≥0,20<0,25~~	~~—~~	~~30~~	~~20~~
~~≥0,25<0,33~~	~~—~~	~~45~~	~~30~~
~~≥0,33<0,40~~	~~—~~	~~60~~	~~30~~
~~≥0,40<0,50~~	~~60~~	~~75~~	~~40~~
~~≥0,50<0,60~~	~~70~~	~~90~~	~~50~~
~~≥0,60<0,80~~	~~85~~	~~110~~	~~60~~
~~≥0,80<1,00~~	~~95~~	~~130~~	~~70~~
~~≥1,00<1,20~~	~~110~~	~~150~~	~~80~~
~~≥1,20<1,50~~	~~120~~	~~165~~	~~90~~
~~≥1,50<1,90~~	~~130~~	~~180~~	~~100~~
~~≥1,90<2,50~~	~~—~~	~~205~~	~~110~~
~~≥2,50<3,20~~	~~—~~	~~230~~	~~125~~
~~≥3,20<4,00~~	~~—~~	~~250~~	~~135~~

~~Table 10.6.4 Wrap test for adhesion of coating~~ *(this table is to be deleted)*

~~Coating~~	~~Diameter of coated wire mm~~	~~Maximum ratio of mandrel to wire diameter~~
~~Grade 1 and 2~~	~~<1,5~~	~~4~~
-	~~≥1,5~~	~~6~~
~~Grade 3~~	~~<1,5~~	~~2~~
-	~~≥1,5~~	~~3~~

6.4 Tests on completed ropes

6.4.1 Every length of steel wire rope is to be subjected to a breaking strength test.

6.6 Identification

6.6.1 All completed ropes are to be identified with attached labels detailing the rope construction type, diameter, ~~and~~ length, gross weight, net weight, reel/coil number, manufacturer, origin, maximum wire diameter and metallic cross-sectional area. Other information, such as rope grade, may be included upon agreement between the purchaser and supplier.

6.7 Certification

6.7.2 Each test certificate is to contain, as a minimum, the following ~~particulars~~ items. Other items, such as lay type and direction, may be included if specified by the purchaser:

- Certificate number
- Date of issue of the certificate
- ~~Purchaser's name and order number~~. Name and address of the manufacturer.
- Details of the rope construction.
- Rope designation and rope grade.
- Core material.
- Grade of zinc coating/wire finish.
- Mechanical test results.
- Adhesion test results.
- Dimensions, including maximum wire diameter and metallic cross-sectional area.
- Method of breaking load testing.
- ~~Breaking load~~ Minimum breaking force.

Chapter 13
Requirements for Welded Construction

■ *Section 8*
Specific requirements for welded aluminium

8.4 ~~Non-destructive examination~~ Non-Destructive Examination

(Part only shown)

8.4.1 The requirements of *Ch 13, 1.11 ~~Non-destructive examination~~ Non-Destructive Examination of welds* and *Ch 13, 2.12 ~~Non-destructive examination~~ Non-Destructive Examination of steel welds* apply with the following additional provisions~~;~~:

(b) The acceptance criteria for surface imperfections of aluminium welds are to be in accordance with *Table ~~13.8.3 Radiographic acceptance~~ 13.8.2 Acceptance criteria for ~~internal~~ surface imperfections of aluminium*.

(c) The acceptance criteria for internal imperfections of aluminium welds using RT and RT-D methods are to be in accordance with *Table 13.8.3 Radiographic acceptance criteria for ~~internal~~ volumetric imperfections of aluminium*.

Table 13.8.2 Acceptance criteria for surface imperfections of aluminium

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria	
Crack and crater crack	100 and 104	Not permitted	
Lack of fusion	401	Not permitted	
Incomplete root penetration in butt joints welded from one side	4021	Not permitted	
Surface pore	2017	Thickness (*t*)	
		0,5 mm < t ≤ 3,0 mm $d \le 0{,}2s$ or $0{,}2a$	t > 3,0 mm $d \le 0{,}3s$ or $0{,}3a$ or 1,5 mm (whichever is the lesser)
End crater pipe	2025	$h \le 0{,}2t$ (maximum 1,5 mm)	
Linear porosity (*see* Note 1)	2014	Not permitted	
Uniformly distributed porosity (*see* Note 2)	2018	≤ 1% of area	
Clustered porosity	2013	Not permitted	
Continuous undercut	5011	Thickness (*t*)	
		0,5 mm < t ≤ 3,0 mm $h \le 0{,}1t$	t > 3,0 mm $h \le 0{,}1t$ or 0,5 mm (whichever is the lesser)
Intermittent undercut	5012	Thickness (*t*)	
		Short imperfections only (*see* Note 4) 0,5 mm < t ≤ 3,0 mm $h \le 0{,}1t$	Short imperfections only (*see* Note 4) t > 3,0 mm $h \le 0{,}1t$ or 1,0 mm (whichever is the lesser)
		Smooth transition to parent material is required. Intermittent undercut is not to be regarded as a systematic imperfection	
Excess weld metal (*see* Note 3)	502	$h \le$ 1,5 mm + $0{,}15b$ or 8,0 mm (whichever is the lesser)	
Excess convexity	503	$h \le$ 1,5 mm + $0{,}15b$ or 4,0 mm (whichever is the lesser)	
Insufficient throat thickness	5213	$h \le 0{,}2a$ or 1,5 mm (whichever is the lesser)	
Excess penetration	504	$h \le$ 4,0 mm	
Overlap	506	Not permitted	
Sagging	509	Short imperfections (*see* Note 4)	
Incompletely filled groove	511	$h \le 0{,}1t$ or 1,0 mm (whichever is the lesser)	
Excess asymmetry of fillet weld (excessive or unequal leg length)	512	$h \le$ 2,0 mm + $0{,}25a$	
Root concavity (*see* Note 3)	515	$h \le 0{,}1t$ or 1,0 mm (whichever is the lesser)	

Incorrect root gap for fillet welds	617	h ≤ 0,5 mm + 0,15a or 4,0 mm (whichever is the lesser)
Linear misalignment ~~(*see* Notes 4 and 5)~~	507	~~h ≤ 0,1t or 1,0 mm (whichever is the lesser)~~ Plates and longitudinal welds h ≤ 0,3t or 4,0 mm (whichever is the lesser)
		Circumferential welds h ≤ 0,3t or 6,0 mm (whichever is the lesser)
Poor restart	517	Not permitted
Stray arc	601	Not permitted
Spatter	602	Not permitted
Angular misalignment	508	(*see* Note ~~6~~5)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

Note *1.* For these acceptance criteria, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.

Note *2.* To be in accordance with EN ISO 10042.

Note *3.* A smooth transition is required.

Note *4.* ~~Linear misalignment is to be a maximum of 0,5 mm in highly stressed areas. For other areas, the linear misalignment is to be a maximum of 1,0 mm locally, where the sum of the length of imperfection is not more than 10% of the weld length.~~For either continuous or intermittent undercut, or sagging, only short imperfections are allowed.

The definitions of short imperfections are as follows:

For welds 100 mm long or longer: Imperfections whose total length is not greater than 25 mm in the 100 mm of the weld which contains the greatest number of imperfections.

For welds less than 100 mm long: Imperfections whose total length is not greater than 25% of the length of the weld.

~~**Note** *5.* The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide.~~

Note ~~*6*~~*5.* Angular misalignment shall be mutually agreed between the designer and the fabricator.

Table 13.8.3 Radiographic acceptance criteria for ~~internal~~ volumetric imperfections of aluminium

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria (*see* Notes 1 ~~&~~ and 2)
Crack	100	Not permitted
Lack of fusion	401	~~Not permitted~~ Short imperfections permitted (*see* Note 4)

		$h \leq 0,2t$ or $0,2a$ or 2,0 mm max (whichever is the lesser)
Incomplete penetration	402	~~Not permitted~~ Partial penetration
		Short imperfections (*see* Note 4) permitted but not systematic imperfections $h \leq 0,2s$ or 2,0 mm max (whichever is the lesser)
		Full penetration
		Not permitted
Incomplete penetration for fillet welds	4021	Short imperfections only (*see* Note 4) $h \leq 0,2a$ or 2,0 mm max (whichever is the lesser)
Gas pores	2011	$d \leq 0,3s$ or 0,3-a or 5,0 mm max (whichever is the lesser)
Linear porosity	2014	~~Assess as lack of fusion~~ Not permitted
Uniformly distributed porosity (*see* Note 3)	2012	Thickness (*t*) ~~0,5 < t < 3 mm ≤ 2% of area L = 100 mm~~ ~~3 < t < 12 mm ≤ 4% of area L = 100 mm~~ ~~12 < t < 30 mm ≤ 6% of area L = 100 mm~~ ~~t > 30 mm ≤ 8% of area L = 100 mm~~
		< 0,5 mm ≤ 2%
		0,5 mm to 3,0 mm ≤ 2%
		> 3,0 mm to 12,0 mm ≤ 4%
		> 12,0 mm to 30,0 mm ≤ 6%
		> 30,0 mm ≤ 8%
Clustered (localised) porosity (*see* Note 3)	2013	Thickness (*t*)
		≥ 0,5 mm $d_A \leq 20,0$ mm or d_A max $\leq w_p$ (whichever is the lesser)
Elongated cavity and wormholes (*see* Note 3)	2015 and 2016	$l \leq$ 0,3-s or $0,3a$ or 4,0 mm max (whichever is the lesser)
Oxide inclusion	303	Short imperfections only (*see* Note 4) $l \leq$ 0,5-s or $0,5a$ or 5,0 mm max (whichever is the lesser)
Tungsten inclusion	3041	$l \leq$ 0,3-s or $0,3a$ or 4,0 mm max (whichever is the lesser)

<table>
<tr><td>Copper inclusion</td><td>3042</td><td>Not permitted</td></tr>
<tr><td colspan="3">Symbols</td></tr>
<tr><td colspan="3">d = diameter of a gas pore
s = nominal butt weld thickness
t = material thickness
w_p = width of weld
d_A = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld
L = any 100 mm testing length, in ~~(~~millimetres~~)~~</td></tr>
<tr><td colspan="3">**Note** *1*. Any two adjacent imperfections separated by a distance smaller than the major dimension of the smaller imperfection shall be considered as a single imperfection.
Note *2*. Indications shall not be divided into different ranges L.
Note *3*. Further guidance regarding assessment and determination of porosity areas and summation of acceptable areas may be referenced within the informative annexes of ISO 10675-2 and ISO 10042.
Note *4*. The definitions of short imperfections are as follows:
For welds 100 mm long or longer: Imperfections whose total length is not greater than 25 mm in the 100 mm of the weld which contains the greatest number of imperfections.
For welds less than 100 mm long: Imperfections whose total length is not greater than 25% of the length of the weld.</td></tr>
</table>

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